Compression stockings significantly improve hemodynamic performance in post-thrombotic syndrome irrespective of class or length

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Background: **Graduated elastic compression (GEC) stockings have been demonstrated to reduce the morbidity associated with post-thrombotic syndrome. The ideal length or compression strength required to achieve this is speculative and related to physician preference and patient compliance. The aim of this study was to evaluate the hemodynamic performance of four different stockings and determine the patient's preference.**

Methods: **Thirty-four consecutive patients (40 legs, 34 male) with post-thrombotic syndrome were tested with four different stockings (Mediven plus open toe, Bayreuth, Germany) of their size in random order: class 1 (18-21 mm Hg) and class II (23-32 mm Hg), below-knee (BK) and above-knee thigh-length (AK). The median age, Venous Clinical Severity Score, Venous Segmental Disease Score, and Villalta scale were 62 years (range, 31-81 years), 8 (range, 1-21), 5 (range, 2-10), and 10 (range, 2-22), respectively. The C of $C_{0\text{-}6}E_sA_{s,d,p}P_{r,o}$ was $C_0 = 2$, $C_2 = 1$, $C_3 = 3$, $C_{4a} = 12$, $C_{4b} = 7$, $C_5 = 12$, $C_6 = 3$. Obstruction and reflux was observed on duplex in 47.5% legs, with deep venous reflux alone in 45%. Air plethysmography was used to measure the venous filling index (VFI), venous volume, and time to fill 90% of the venous volume. Direct pressure measurements were obtained while lying and standing using the PicoPress device (Microlab Elettronica, Nicolò, Italy). The pressure sensor was placed underneath the test stocking 5 cm above and 2 cm posterior to the medial malleolus. At the end of the study session, patients stated their preferred stocking based on comfort.**

Results: **The VFI, venous volume, and time to fill 90% of the venous volume improved significantly with all types of stocking versus no compression. In class I, the VFI (mL/s) improved from a median of 4.9 (range, 1.7-16.3) without compression to 3.7 (range, 0-14) BK (24.5%) and 3.6 (range, 0.6-14.5) AK (26.5%). With class II, the corresponding improvement was to 4.0 (range, 0.3-16.2) BK (18.8%) and 3.7 (range, 0.5-14.2) AK (24.5%). Median stocking pressure (mm Hg) as measured with the PicoPress in class I was 23 (range, 12-33) lying and 27 (range, 19-39) standing ($P < .0005$) and in class II was 28 (range, 21-40) lying and 32 (range, 23-46) standing ($P < .0005$). There was a significant but weak correlation (Spearman) between stocking interface pressure measured directly with the PicoPress and the VFI improvement (baseline VFI−compression VFI) at $r = .237$; $P = .005$. Twenty-one patients (legs) changed their preference of compression and 38% of these (8/21 patients, 9/21 legs) preferred an AK-GEC stocking.**

Conclusions: **Compression significantly improved all hemodynamic parameters on air plethysmography. However, the hemodynamic benefit did not significantly change with the class or length of stocking. These results support the liberal selection of a GEC stocking based on patient preference. (J Vasc Surg 2013;58:158-65.)**

Graduated elastic compression (GEC) stockings are an established intervention for the prevention[1-4] and the treatment of the post-thrombotic syndrome (PTS).[5] Although clinical evidence of their efficacy is proven, the optimal compression strength or length of stocking required to achieve this is not known. Furthermore, there is usually a trade-off between compression strength and length of stocking against compliance. Stronger or longer stockings are perceived to be better but are also perceived to be harder to apply and wear for longer periods. Many physicians are rigid in their prescribing, insisting that a below-knee (BK) or above-knee thigh-length (AK) GEC stocking is better. A class II (23-32 mm Hg) stocking is usually chosen over a class I (18-21 mm Hg), and measuring charts are relied upon to select the appropriate size for that patient. This takes place usually without the patients themselves testing and wearing the various stockings that are available in order to state their preference. Lack of compliance often hampers the results of clinical trials comparing stockings in the prevention and treatment of PTS. Therefore, an objective assessment of stocking performance, using improvements in hemodynamic parameters, may provide meaningful information as to the optimal stocking for treating PTS.

The main hypothesis is to test a common assumption that the greater the length and compression of stocking, the greater the immediate reduction in reflux, the main pathophysiological abnormality in PTS. The aim was to

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examine objectively which strength and/or length of stocking was the most effective at reducing reflux. A secondary aim was to evaluate patient preferences as to which GEC stocking they would prefer to wear having tried and tested all four alternatives during the study session.

METHODS

Study design. This was a prospective study on 34 consecutive patients (40 legs) with PTS at a single district general hospital. All patients invited into the study had a prior diagnosis of PTS using criteria based on physical symptoms and clinical signs as recommended.[6] They were given a participant information leaflet at the time of their follow-up visit from the venous clinic (29 patients) or new referrals from the anticoagulation clinic because of persisting leg symptoms (five patients, all unilateral). Patients were given a study appointment a week later and requested to wear their usual compression as prescribed by the vascular surgeon or family doctor. Written informed consent was obtained from all participating patients prior to the hemodynamic measurements. Inclusion criteria included patients with leg symptoms (ache, heaviness, swelling, cramps, itching, or tingling) and signs (edema, telangiectasiae, pigmentation, secondary varicose veins, and ulceration) attributable to PTS, a previous deep vein thrombosis (DVT) >6 months old with duplex evidence of deep venous damage (reflux or obstruction or both). Exclusion criteria consisted of a recent <3 months recurrent DVT or venous ulceration >1-cm diameter.

Four different stockings were used to determine the best one at reducing reflux in that leg. Each patient acted as his or her own control. The stockings (Mediven plus open toe, Bayreuth, Germany) were applied in random order using sealed envelopes. The four stockings used were class I and class II, BK and AK (thigh length). Each AK stocking had a waist attachment, but this was not applied around the waist during the test in order to avoid abdominal compression as a possible confounding variable. The stocking size for the leg was determined by measuring the ankle circumference at the narrowest part and the calf circumference at its widest part. The appropriate stocking was then selected using the manufacturer's sizing chart.

The C part of CEAP,[7] the Venous Clinical Severity Score (VCSS),[8] and the Villalta scale (VS)[9] are established assessment questionnaires and were used to grade the clinical severity of PTS. The Venous Segmental Disease Score (VSDS)[8] was determined with duplex and used to identify the type and extent of the hemodynamic impairment. All duplex evaluations were carried out by an accredited vascular sonographer (M.A.) using a 7-MHz linear transducer attached to an ultrasound machine (iU22; Philips, Bothwell, Wash). Reflux duration of >1 second was considered significant for the deep veins.[10] Significant obstruction was defined as occlusion or >50% narrowing of at least half of the segment of the examined vein.[8] The study session lasted approximately 1 hour. At the beginning of the session, patients were informed that they would be asked to state their preferred stocking based on comfort. At the end of the session, each patient was offered a prescription for his or her chosen stocking, which was recorded.

Ethical approval for this study was granted by the North London (Region 3) Research Ethics Committee (REC: 11/LO/0345).

Stocking interface pressure. Stocking interface pressure was measured using the PicoPress transducer (Microlab Elettronica, Nicolò, Italy). This instrument was chosen because it had the least coefficient of variation and the highest accuracy compared with two other instruments.[11] The device comprises a 50-mm inflatable diaphragm (sensor), 0.2 mm thick, attached to a handheld transducer via a narrow tube.[12] The sensor was placed between the stocking and the leg, 5 cm above and 2 cm posterior to the medial malleolus. Care was taken to ensure the sensor was flat by pulling on the connecting tube and by avoiding any bony prominences.[13,14] When 2 mL of air, quantified by a precalibrated syringe that is an integral part of the transducer apparatus, was injected into the sensor, the interface pressure was displayed on the screen. Dynamic measurements were taken lying and standing without the need to recalibrate the probe.

Air plethysmography (APG). APG (APG-1000 apparatus, ACI Medical LLC, San Marcos, Calif) comprised a sensor air cuff, inflation pump, pressure/volume transducer, and processing software. The method has been described and validated previously.[15] The sensor measures changes in pressure that are calibrated to reflect changes in volume. The air cuff was applied around the calf directly on the skin for baseline measurements and then over each stocking in the supine position. Values were taken from continuous recordings from the point at which the patient stood up preceded by a period of leg elevation. The venous filling index (VFI) in mL/s is derived from the venous volume (VV) in mL divided by the venous filling time (VFT90) in seconds, which is the time taken to achieve 90% of the VV. All three parameters were recorded for each of the five tests. A VFI ≤2 mL/s was considered normal. The APG was used in preference to photoplethysmography because it has been shown to be a better method of evaluating reflux,[16] although inherent variations in method error of 13.4% in measuring the VFI are acknowledged.[17]

Statistical analysis. Data were collected onto spreadsheets throughout the duration of the study and transferred into the IBM SPSS statistics package version 19 (IBM Corporation, Armonk, NY) at completion. Improvement using APG was defined as the difference between the initial parameter values without compression from the values recorded using each stocking. The nonparametric Wilcoxon signed rank test was used to assess the significance of an improvement. Correlations between reflux without a stocking compared with improvements in VFI were performed using the Spearman rho test.

Pilot data from our department demonstrated a stepwise reduction in VFI from no stocking to a BK stocking and then with an AK stocking. Power calculations for a type I error (alpha) of 0.05 and a type II error (beta)

Table I. Characteristics of 40 legs studied

	Median	*Interquartile range*	*Range*
Age	62	52-73	31-81
VCSS	8	5-10	1-21
Villalta scale	10	5-14	2-22
Patient part	4	1-7	0-11
Physician part	5.5	3-9	0-13
Calf circumference/mm	40	37-44	33-55
Ankle circumference/mm	24	22-26	21-32
Stocking size[a]	4	3-5	1-7

VCSS, Venous Clinical Severity Score.
[a]Based on the Mediven measuring chart.

of 0.2 revealed that a minimum of 36 legs were required to demonstrate a difference of 1.5 in the VFI between a BK and an AK stocking with a standard deviation of 2.

RESULTS

Patient characteristics. Forty legs (34 male, 23 left legs) from 34 consecutive patients (28 male) with PTS were studied. Six patients had bilateral disease. The median age was 62 years (range, 31-81 years). The distribution of the C part of the $C_{0\text{-}6}E_sA_{s,d,p}P_{r,o}$ classification was $C_0 = 2$, $C_2 = 1$, $C_3 = 3$, $C_{4a} = 12$, $C_{4b} = 7$, $C_5 = 12$, $C_6 = 3$. Severity characteristics, leg measurements, and stocking sizes are illustrated in Table I. The calf cross-sectional area at its widest point was calculated by circumference^2 /4π. It ranged from a factor of 2.1 to 4.0 times the value of the narrowest ankle cross-sectional area (median 2.7, interquartile range, 2.5-3).

Pattern of hemodynamic impairment. The median VSDS as determined using duplex was 5 (range, 2-10) out of a theoretic total score of 20. The median reflux and obstruction component of this score was 4 (range, 0-7) and 1 (range, 0-5), respectively, indicating that there was more reflux than obstruction in the legs studied. The proportions of legs with reflux, obstruction, or both are shown in Fig 1. Of the legs with only reflux, 9 of 18 (50%) had concurrent reflux in the saphenous trunks. This compares with 6 of 19 (31.6%) legs with combined reflux and obstruction. None of the patients had complete occlusion of the femoral or popliteal veins or isolated calf pathology.

Attempts were also made to match stockings based on anatomical sites and the pathophysiology of disease. When legs were divided into calf vein pathology and above (n = 28, 70%) or popliteal vein pathology and/or above (n = 12, 30%), the differences between the groups were not significant at BK I ($P = .679$), BK II ($P = .274$), AK I ($P = .275$), and AK II ($P = .184$). Similarly, when legs were divided into reflux alone versus reflux and obstruction, the results were BK I ($P = .171$), BK II ($P = .171$), AK I ($P = .186$), and AK II ($P = .224$). There was a very poor correlation between the VSDS score and the change in VFI with a stocking ($r = .166$; $P = .035$), too weak for meaningful conclusions. The inferior vena cava and iliac veins were not assessed.

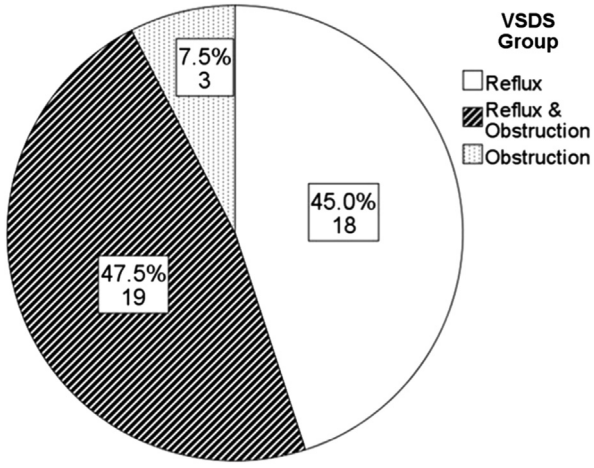

Fig 1. Type and pattern of infrainguinal venous disease in the study group according to the Venous Segmental Disease Score (*VSDS*). The number of legs are given below the percentages.

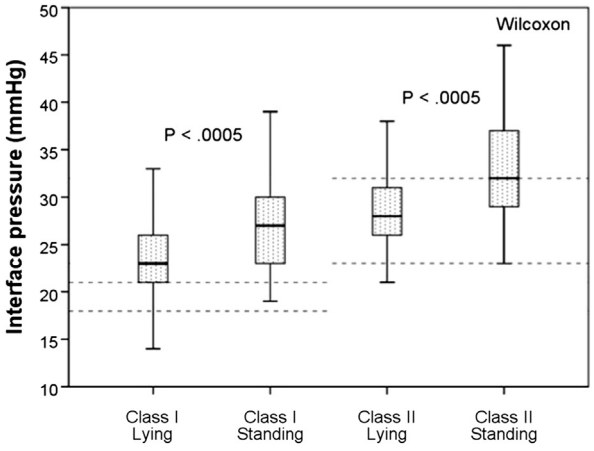

Fig 2. Interface pressure 5 cm above and posterior to the medial malleolus in relation to stocking class and position. The *dashed lines* represent the manufacturer's compression specifications.

Interface pressures. As shown in Fig 2, the median interface pressure either reached or exceeded the pressure ranges stated by the manufacturer. The interface pressure was also significantly higher when standing than when lying. There was a significant but weak correlation (Spearman) between stocking pressure measured directly with the Pico-Press and the VFI improvement (baseline VFI − compression VFI) with all four stockings at $P = .005$; $r = .237$.

APG parameters with different stockings. The VFI, VFT90, and VV significantly improved with all types of stocking vs no compression. The values of each parameter are presented in Table II.

Table II. Changes in air plethysmography parameters following the application of various stockings

	VFI	*VFT90*	*VV*
No compression	4.9 (5.1)	20 (17)	121 (87)
BK class I	3.7 (4) 25%	23 (18) 18%	100 (69) 17%
BK class II	4 (4.3) 19%	27 (20) 36%	112 (80) 7%
AK class I	3.6 (3.5) 27%	26 (16) 31%	119 (76) 2%
AK class II	3.7 (4.3) 25%	26 (16) 31%	106 (77) 12%

AK, Above-knee thigh-length; *BK,* below knee; *VFI,* venous filling index in mL/s; *VFT90,* venous filling time to 90% of venous volume in seconds; *VV,* venous volume in mL.
Results are expressed as median (interquartile range) percentage improvement.

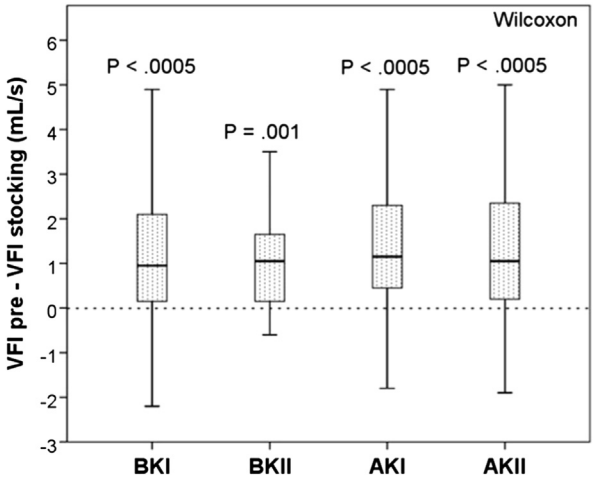

Fig 3. Significant reductions in venous filling index (*VFI*) in relation to class and length of stocking. The *dashed line* represents no improvement. *AK,* Above knee; *BK,* below knee.

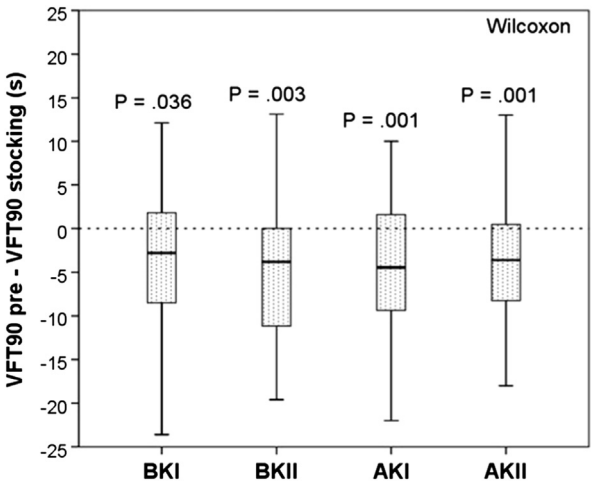

Fig 4. Significant increases in venous filling time (*VFT*) in relation to class and length of stocking. The *dashed line* represents no improvement. *AK,* Above knee; *BK,* below knee.

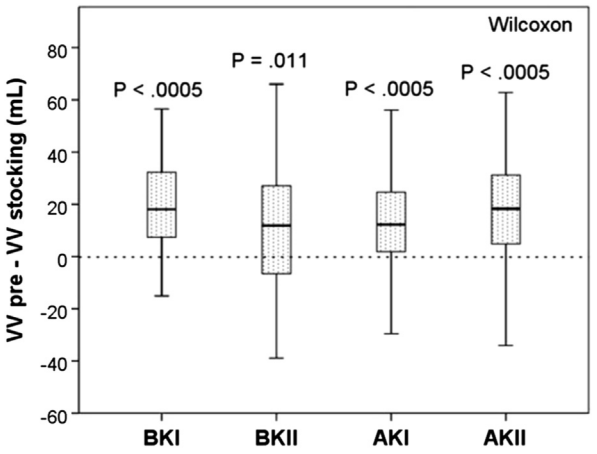

Fig 5. Significant reductions in venous volume (*VV*) in relation to class and length of stocking. The *dashed line* represents no improvement. *AK,* Above knee; *BK,* below knee.

Regarding VFI.

1. The number (percentage) of legs with a normal VFI (≤2 mL/s) without a stocking was 4 of 40 (10%). The number of legs with a normal VFI with a stocking in place was BK class I: 11 of 40 (27.5%), BK class II: 7 of 40 (17.5%), AK class I: 12 of 40 (30%), and AK class II: 10 of 40 (25%). This indicated that a GEC stocking was unable to abolish reflux in the majority of patients.
2. The VFI was reduced in 28 of 40 (70%) of legs irrespective of the class or length. When stratified by stocking type, a reduction in VFI was demonstrated in 32, 31, 33, and 32 legs, with a BK class I, BK class II, AK class I, and AK class II, respectively. This indicated that a GEC stocking was successful in reducing reflux in most patients.

APG improvements and correlations with reflux. As seen in Figs 3-5, each stocking succeeded statistically in improving all APG parameters (VFI, VFT90, and VV) compared without compression. However, there was no statistical difference between the magnitude of improvement between stockings. This indicated that stocking class or length were unrelated variables in reducing reflux.

The degree of improvement in the stocking VFI appeared to correlate with the prestocking VFI (Fig 6, Table III), indicating that greater reflux at baseline resulted in more benefit with compression. The correlations were all moderate to poor, but significant, with no difference between stocking class or length.

Patient preferences. Patients were questioned on their use of compression by question 10 of the VCSS in order to determine compliance. The results were not used (7/34, 20.6%), intermittent use (3/34, 8.8%), most days (3/34, 8.8%), and full compliance (21/34, 61.8%). On arrival for the study, eight legs had no compression, two legs were in compression bandages, one had a midcalf

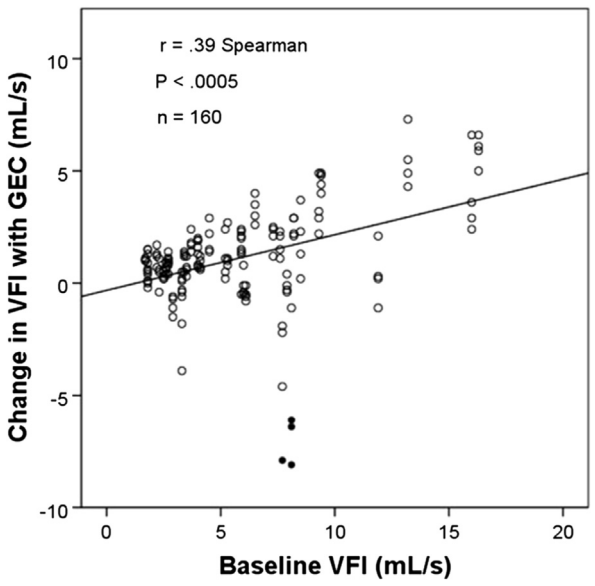

Fig 6. Significant correlation between the degree of reflux without compression and the improvement of the venous filling index (*VFI*) with graduated elastic compression (*GEC*). In two patients/four legs (*filled circles*), the VFI significantly deteriorated.

GEC stocking, and one had a BK flight stocking. The complete stratification of compression and the number of subsequent changes are illustrated in Fig 7. After the study session, patient preferences and physician insistence that a stocking was necessary resulted in a change or a new stocking prescription in 31 legs as follows: AK = 9, BK = 9, class change = 4, size change = 7, and a change to a closed toe = 2. Interestingly, 21 (52.5%) patients indicated they wanted to change their compression, and 38% of these (8/21 patients, 9/21 legs) preferred an AK stocking.

Short-term follow-up on whether these changes actually took place did not occur and was not part of the study protocol. However, these results indicate that significant changes (length, class, or size) are required in determining a suitable GEC in 29 of 40 (72.5%) legs and that an AK stocking may be preferable in many patients.

DISCUSSION

The use of APG in evaluating the performance of compression was documented as early as 1987,[15] and since then, there have been studies comparing stockings in relation to manufacturer[18] and compression strength.[19] There is a systematic review on 14 of 29 randomized controlled trials comparing knee-length versus thigh-length thromboembolic deterrent stockings for the prevention of DVT.[20] They concluded that they were equally effective, but the former may offer advantages in terms of patient compliance and cost. Compression strength or hemodynamic parameters were not reported in that analysis.

To our knowledge, this is the first study to examine the hemodynamic performance of GEC strength as well as stocking length using APG in patients with PTS. The combination of circumference measurements, interface pressure, and APG as an evaluation technique was suggested in a consensus paper from members of the International Compression Club.[21] Although this paper was written in relation to compression bandages, the usefulness of these measurements was illustrated.

Two previous studies are noteworthy. In one study, 11 patients were randomly allocated to a sequence of four brands of knee-high, 30- to 40-mm Hg stockings.[18] The authors found that stockings decreased the VFI and VV with an increase in the VFT90, in support of the current study, but in contrast, none of the parameters studied were statistically significant. Another study on 19 female patients (20 legs) with moderate varicose veins used lightweight compression stockings of 7, 10, and 14 mm Hg.[19] They found that the mean VFI decreased from 5.7 mL/s without stockings to 4.6, 3.9, and 3.4 mL/s, respectively ($P < .0002$), indicating that even lightweight compression can have a significant effect on venous hemodynamics.

In our study, 10% of the PTS legs had a normal initial value of VFI without compression. Approximately 25% of patients with PTS did not improve as a result of wearing a GEC stocking, and only 25% to 30% had a VFI that returned to normal. The reasons for this are likely to be multi-factorial. First, the properties of a GEC stocking are that it must be graduated with decreasing pressure from the ankle upward. While this is strictly adhered to by the manufacturer ex vivo, the situation is often different on the leg of a patient. In an open study of 50 patients with chronic venous disease (CVD) using round knitted GEC stockings and interface pressure measurements at five defined points, only 66% had a continuous distal-proximal descending pressure gradient.[22] In another study in 89 patients following hip or knee replacement, a reversed pressure gradient was detected in 54% of patients wearing a BK-GEC stocking.[23] Its presence was associated with a significantly higher incidence of DVT (25.6% vs 6.1%; $P = .026$). Reversed pressure gradients could also hamper venous return, resulting in adverse changes to the VFI, VFT90, and VV.

Second, stockings can cause band-like constrictions if they roll down, form overlapping pleats with poor application, or constrict from wide discrepancies in the cross-sectional areas of the leg. The current study observed a range in cross-sectional area from a factor of 2.1 to 4.0, comparing the point at the narrowest part of the ankle to the widest part of the calf. Third, the reason for a failure to restore the VFI to normal may relate to ineffective compression strength. A study on 12 patients with venous ulcers and popliteal vein reflux >1 second on duplex revealed that a reduction in VFI was achieved only with a thigh pressure of 60 mm Hg, intolerable with elastic material but tolerated using inelastic compression.[24] They concluded that the compression exerted using a thigh length class II stocking, 15 mm Hg at the thigh, is too low to produce significant hemodynamic effects, although

Table III. Correlation between baseline VFI against the change in VFI (baseline VFI − stocking VFI) following the application of various stockings

	VFI improvement (median and interquartile range)	r *value (Spearman rho test)*	P *value (Spearman rho test)*
Class I (18-21 mm Hg)	1.10 (0.3-2.18)	.420	<.0005
Class II (23-32 mm Hg)	1.05 (0.2-2.08)	.350	.001
Below knee	1.0 (0.13-2.08)	.327	.003
Above knee (thigh-length)	1.10 (0.4-2.38)	.452	<.0005
All stockings summary	1.10 (0.2-2.10)	.390	<.0005

VFI, Venous filling index in mL/s.

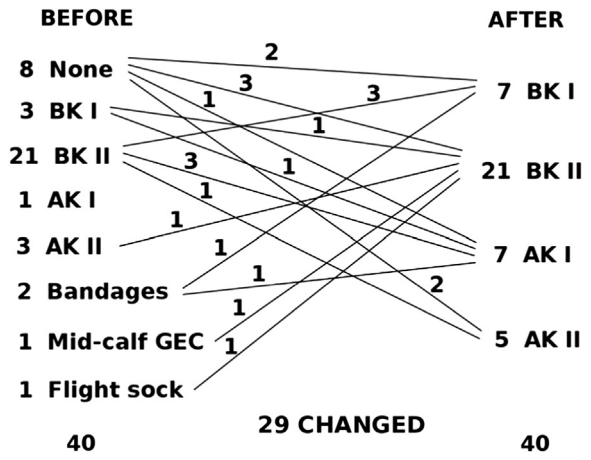

Fig 7. Significant changes (strength, length, or size) to compression as a result of the study environment. The *numbers on the lines* indicate the number of changes. The seven changes in stocking size (six below knee [*BK*], one above knee [*AK*]) are not shown. *GEC,* Graduated elastic compression.

narrowing of the femoral vein was observed using magnetic resonance imaging with a pressure of 7 mm Hg in the supine position.[25] A recent duplex study on eight patients with refluxing great saphenous veins, without deep venous reflux, revealed that an ankle pressure of between 90 mm Hg and 100 mm Hg was unable to abolish reflux in 5 of 8 patients.[26] This pressure was achieved using three sequentially applied 30- to 35-mm Hg stockings. It likely that such high pressures will not be tolerated by patients, increase the difficulty in application, and result in skin trauma with prolonged use. Our study was limited to class I and class II stockings since this was the most common type of stocking prescribed.

In the present study, approximately 72.5% of legs needed to have their compression re-evaluated with eight (20%) presenting at entry into the study without any form of compression and an extra two (5%) with inadequate compression, despite earlier clinical advice. There are several reasons for noncompliance in the literature. In a population-based study of 16,770 patients with CVD, the reasons for discontinuation at a follow-up visit were high cost (33.0%), sweating (27.3%), itching (13.6%), cosmetic (13.6%), edema (6.8%), exudation (3.4%), and difficulty with application (2.3%).[27] In another study of 3144 CVD patients referred to a tertiary practice, the reasons for non-usage were none specified (30%), none prescribed (25%), no benefit (14%), cutting off of the circulation (13%), too hot to wear (8%), soreness (2%), cosmetic (2%), application difficulty (2%), itch or dermatitis (2%), and other (2%).[28] They concluded that the reasons for noncompliance can be grouped into wear/comfort factors and an intangible sense of restriction imposed by the stocking.

A questionnaire survey on 110 of 200 (55% response rate) consecutive CVD patients reported side effects of dry skin (58.5%), slipping (29.1%), and constriction (24.5%) with only 29.1% voting the stocking as "comfortable."[29] Another questionnaire survey on 150 of 207 (72% response rate) PTS patients reported a 74% daily compliance rate, with the main reasons of nonregular use as difficulty in application, discomfort, and their appearance.[30] Furthermore, it is also known that control visits can increase the frequency of GEC stocking use by 37.4%.[27]

The present study has shown that poor compliance may be attributed to rigid prescribing patterns based on a belief that a particular length or strength of stocking is better for the patient. Relying on a manufacturer's chart and the experience of the fitter to select the size is important. However, a stocking testing environment, analogous to a fitting room in a department store, allowing patients to choose their own stocking based on comfort is strongly recommended. This has been shown in this work to result in a change or a new prescription in 72.5% of legs. Although not part of this study, it is likely that such a patient-oriented approach to stocking selection will improve overall compliance. Customization, based on circumferential leg measurements at standardized locations, may reduce the number of patients with reverse pressure gradients, improve comfort, and ultimately result in better compliance. The option to order measure-to-made GEC stockings may be required more often than it is used in day-to-day practice.

Limitations. This study has focused on the effectiveness of stockings at controlling reflux by using the VFI, VFT90, and VV parameters of APG, on the assumption that a reduction in reflux will reduce the morbidity associated with PTS. The reasons for selecting reflux were, first, that it is the most useful diagnostic APG parameter to study,[31-34] and second, because stockings are likely to be more effective at controlling reflux than improving

calf-muscle pump (CMP) function.[18] A third factor likely to determine the morbidity of PTS is the degree of mechanical or functional obstruction to venous return, for example, in obesity.[35] It is not known how GEC may influence this other than by an improvement in CMP function or a reduction in VV. To date, there are no useful diagnostic tests that can quantify outflow resistance, although measurements of outflow fraction with APG can be meaningful in some situations.[36] Ambulatory venous pressure measurement is considered the gold standard test in assessing venous function but was not performed in our cohort for ethical reasons.[37]

CONCLUSIONS

Compression stockings significantly improved hemodynamic performance in patients with PTS, evidenced by a reduction in the rate of venous filling and venous volume with an improvement in reflux duration. The extent of improvement correlated with the initial magnitude of reflux, irrespective of the class or length of stocking. Furthermore, 72.5% of legs required a change of GEC or new prescription, with 8 of 21 (38%) patients preferring an AK stocking. These results support the liberal selection of a GEC stocking based on the preference of the patient.

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AUTHOR CONTRIBUTIONS

Conception and design: CL, MA, GG
Analysis and interpretation: CL, EK, GG
Data collection: CL, MA, EK, GM
Writing the article: CL, EK
Critical revision of the article: MA, EK, GM, GG
Final approval of the article: CL, MA, EK, GM, GG
Statistical analysis: CL
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REFERENCES

1. Kakkos SK, Daskalopoulou SS, Daskalopoulos ME, Nicolaides AN, Geroulakos G. Review on the value of graduated elastic compression stockings after deep vein thrombosis. Thromb Haemost 2006;96:441-5.
2. Giannoukas AD, Labropoulos N, Michaels JA. Compression with or without early ambulation in the prevention of post-thrombotic syndrome: a systematic review. Eur J Vasc Endovasc Surg 2006;32:217-21.
3. Lowe GD. Management of deep vein thrombosis to reduce the incidence of post-thrombotic syndrome. Phlebology 2010;25(Suppl 1):9-13.
4. Aschwanden M, Jeanneret C, Koller MT, Thalhammer C, Bucher HC, Jaeger KA. Effect of prolonged treatment with compression stockings to prevent post-thrombotic sequelae: a randomized controlled trial. J Vasc Surg 2008;47:1015-21.
5. Kahn SR. The post-thrombotic syndrome. Hematology Am Soc Hematol Educ Program 2010;2010:216-20.
6. Kahn SR, Partsch H, Vedantham S, Prandoni P, Kearon C; Subcommittee on Control of Anticoagulation of the Scientific and Standardization Committee of the International Society on Thrombosis and Haemostasis. Definition of post-thrombotic syndrome of the leg for use in clinical investigations: a recommendation for standardization. J Thromb Haemost 2009;7:879-83.
7. Eklöf B, Rutherford RB, Bergan JJ, Carpentier PH, Gloviczki P, Kistner RL, et al. Revision of the CEAP classification for chronic venous disorders: consensus statement. J Vasc Surg 2004;40:1248-52.
8. Rutherford RB, Padberg FT Jr, Comerota AJ, Kistner RL, Meissner MH, Moneta GL. Venous severity scoring: an adjunct to venous outcome assessment. J Vasc Surg 2000;31:1307-12.
9. Kahn SR. Measurement properties of the Villalta scale to define and classify the severity of the post-thrombotic syndrome. J Thromb Haemost 2009;7:884-8.
10. van Bemmelen PS, Bedford G, Beach K, Strandness DE. Quantitative segmental evaluation of venous valvular reflux with duplex ultrasound scanning. J Vasc Surg 1989;10:425-31.
11. Partsch H, Mosti G. Comparison of three portable instruments to measure compression pressure. Int Angiol 2010;29:426-30.
12. Al Khaburi J, Nelson EA, Hutchinson J, Dehghani-Sanij AA. The use of PicoPress transducer to measure sub-bandage pressure. World Acad Sci Eng Tech 2011;81:267-71.
13. Flaud P, Bassez S, Counord JL. Comparative in vitro study of three interface pressure sensors used to evaluate medical compression hosiery. Dermatol Surg 2010;36:1930-40.
14. Al Khaburi J, Nelson EA, Hutchinson J, Dehghani-Sanij AA. Impact of variation in limb shape on sub-bandage interface pressure. Phlebology 2011;26:20-8.
15. Christopoulos DG, Nicolaides AN, Szendro G, Irvine AT, Bull ML, Eastcott HH. Air plethysmography and the effect of elastic compression on venous hemodynamics of the leg. J Vasc Surg 1987;5:148-59.
16. Bays RA, Healy DA, Atnip RG, Neumyer M, Thiele BL. Validation of air plethysmography, photoplethysmography, and duplex ultrasonography in the evaluation of severe venous stasis. J Vasc Surg 1994;20:721-7.
17. Yang D, Vandongen YK, Stacey MC. Variability and reliability of air plethysmographic measurements for the evaluation of chronic venous disease. J Vasc Surg 1997;26:638-42.
18. Zajkowski PJ, Proctor MC, Wakefield TW, Bloom J, Blessing B, Greenfield LJ. Compression stockings and venous function. Arch Surg 2002;137:1064-8.
19. Ibegbuna V, Delis K, Nicolaides AN. Effect of lightweight compression stockings on venous haemodynamics. Int Angiol 1997;16:185-8.
20. Sajid MS, Tai NR, Goli G, Morris RW, Baker DM, Hamilton G. Knee versus thigh length graduated compression stockings for prevention of deep venous thrombosis: a systematic review. Eur J Vasc Endovasc Surg 2006;32:730-6.
21. Partsch H, Clark M, Mosti G, Steinlechner E, Schuren J, Abel M, et al. Classification of compression bandages: practical aspects. Dermatol Surg 2008;34:600-9.
22. Reich-Schupke S, Gahr M, Altmeyer P, Stücker M. Resting pressure exerted by round knitted moderate-compression stockings on the lower leg in clinical practice—results of an experimental study. Dermatol Surg 2009;35:1989-97.
23. Best AJ, Williams S, Crozier A, Bhatt R, Gregg PJ, Hui AC. Graded compression stockings in elective orthopaedic surgery: an assessment of the in vivo performance of commercially available stockings in patients having hip and knee arthroplasty. J Bone Joint Surg Br 2000;82:116-8.
24. Partsch H, Menzinger G, Borst-Krafek B, Groiss E. Does thigh compression improve venous hemodynamics in chronic venous insufficiency? J Vasc Surg 2002;36:948-52.
25. Partsch H, Mosti G, Mosti F. Narrowing of leg veins under compression demonstrated by magnetic resonance imaging (MRI). Int Angiol 2010;29:408-10.
26. Cornu-Thenard A, Benigni JP, Uhl JF. Hemodynamic effects of medical compression stockings in varicose veins: clinical report. Acta Phleb 2012;13:19-23.
27. Ziaja D, Kocełak P, Chudek J, Ziaja K. Compliance with compression stockings in patients with chronic venous disorders. Phlebology 2011;26:353-60.
28. Raju S, Hollis K, Neglen P. Use of compression stockings in chronic venous disease: patient compliance and efficacy. Ann Vasc Surg 2007;21:790-5.

29. Reich-Schupke S, Murmann F, Altmeyer P, Stücker M. Quality of life and patients' view of compression therapy. Int Angiol 2009;28:385-93.
30. Roche-Nagle G, Ward F, Barry M. Current prescribing patterns of elastic compression stockings post-deep venous thrombosis. Phlebology 2010;25:72-8.
31. Nishibe T, Kudo F, Miyazaki K, Kondo Y, Nishibe M, Dardik A. Relationship between air-plethysmographic venous function and clinical severity in primary varicose veins. Int Angiol 2006;25:352-5.
32. Criado E, Farber MA, Marston WA, Daniel PF, Burnham CB, Keagy BA. The role of air plethysmography in the diagnosis of chronic venous insufficiency. J Vasc Surg 1998;27:660-70.
33. Ting AC, Cheng SW, Wu LL, Cheung GC. Air plethysmography in chronic venous insufficiency: clinical diagnosis and quantitative assessment. Angiology 1999;50:831-6.
34. Christopoulos D, Nicolaides AN, Szendro G. Venous reflux: quantification and correlation with the clinical severity of chronic venous disease. Br J Surg 1988;75:352-6.
35. Danielsson G, Eklof B, Grandinetti A, Kistner RL. The influence of obesity on chronic venous disease. Vasc Endovascular Surg 2002;36:271-6.
36. Kalodiki E, Calahoras LS, Delis KT, Zouzias CP, Nicolaides AN. Air plethysmography: the answer in detecting past deep venous thrombosis. J Vasc Surg 2001;33:715-20.
37. Payne SP, Thrush AJ, London NJ, Bell PR, Barrie WW. Venous assessment using air plethysmography: a comparison with clinical examination, ambulatory venous pressure measurement, and duplex scanning. Br J Surg 1993;80:967-70.

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REQUEST FOR SUBMISSION OF SURGICAL ETHICS CHALLENGES ARTICLES

The Editors invite submission of original articles for the Surgical Ethics Challenges section, following the general format established by Dr. James Jones in 2001. Readers have benefitted greatly from Dr. Jones' monthly ethics contributions for more than 6 years. In order to encourage contributions, Dr. Jones will assist in editing them and will submit his own articles every other month, to provide opportunity for others. Please submit articles under the heading of "Ethics" using Editorial Manager, and follow the format established in previous issues.